SOLAR PROMINENCES AND TERRESTRIAL MAGNETISM.

SINCE the year 1871 the Italian astronomer, Prof. Tacchini, has been daily making spectroscopic observations of the sun, noting the number, size and position of the prominences visible on the solar limb. A preliminary study of this very valuable homogeneous series of data rendered it possible to demonstrate that the variation of the frequency of occurrence of these phenomena followed a very general law, the number waxing and waning at intervals of about eleven years, and synchronising with the variation of the number of spots on the sun's disc. This result was pointed out some time ago in the pages of this Journal (vol. lxvi. p. 248), and it was there further stated that there were in addition subsidiary maxima and minima superimposed on the main eleven-year curve.

This preliminary study dealt with the prominences visible on the sun's limb *in toto*, and did not consider their frequency in any particular part of it.

A subsequent analysis indicated, however, that by taking the solar limb to pieces, so to speak, and dealing with the individual parts of it, very interesting results might accrue. This work has recently been completed, and it was found that the frequency of prominences varied according to the particular solar latitude examined, and that the phenomena of terrestrial magnetism were very closely connected with these variations.

In a recent communication to the Royal Society[1] the comparison of these two classes of phenomena, as mentioned above, has been made in some detail, and the present article gives a brief account of the conclusions derived from the inquiry.

For the reduction of the prominence observations the limb of the sun was divided into parts ten degrees in length, corresponding with ten-degree zones of solar latitude north and south, and each zone was examined and discussed by itself. Further, the observations for every three months were, in the first instance, grouped together, and the percentage frequency for each of these periods was determined individually.

In this way a set of eighteen curves, nine for each hemisphere, was made, showing the variation from year to year of the percentage frequency of prominence activity in each ten-degree zone.

In the curves accompanying the present article (Fig. 1) the above-mentioned set, except those for 80°–90° north and south, was grouped in pairs, thus representing the percentage frequency of prominences in each hemisphere for zones of 20° of latitude, 0°–20°, 20°–40°, &c., since it was found that this reduction could be made without losing any of the characteristic variations.

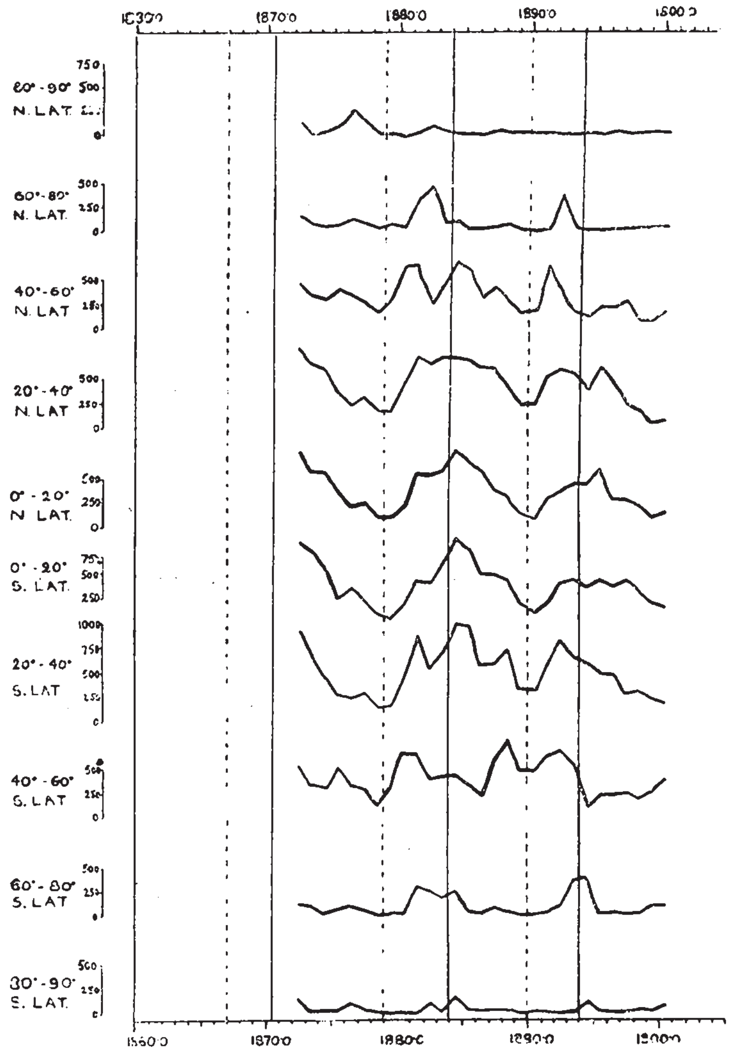

FIG. 1.—Curves showing the percentage frequency of solar prominences for each 20 zone N. and S. (The continuous and broken vertical lines indicate the epochs of sun-spot maxima and minima respectively.)

An examination of these curves shows that they differ very considerably one from the other as we proceed from the equatorial to the polar zones. Generally speaking, the curves representing the variations for each of the zones, 0°–20° north and south, conform with the sun-spot curve; that is, the maxima and minima occur at about the epochs of sun-spot maxima and minima. Those for the two zones 20°–40°, in both hemispheres, conform also in the main to the general sun-spot curve, but in addition they display subsidiary maxima or changes of curvature superimposed on the main curve.

The curves for the two zones, 40°–60° north and south, have, on the other hand, hardly any likeness to the sun-spot curve, but are made up of a series of prominent maxima representing special outbursts of prominence activity.

Passing to the curves corresponding to the next zones, *i.e.* 60°–80° north and south, these indicate two prominent outbursts lasting for a short period, showing that this region of the sun is, as a rule, practically free from prominence activity; in the remaining zones, 80°–90° north and south, the variation is small, and is a faint echo of the condition of affairs in the neighbouring zone 60°–80°.

The data regarding the magnetic phenomena which were employed were those brought together by Mr. William Ellis, who very kindly brought the whole of them up to date for the purposes of the present inquiry.

Two classes of magnetic phenomena were dealt with, namely, the variations from year to year of the diurnal range of the declination and horizontal force, and magnetic disturbances. As regards the former, Mr. Ellis has shown that the curves indicating these variations are very similar to that of the general sun-spot curve; in fact, the curves were found to be almost identical in all their smaller irregularities. The second class of phenomena, namely, the magnetic disturbances, which are more irregular in occurrence, has been classified by Mr. Ellis into five groups, and tabulated by him

[1] "The Relation between Solar Prominences and Terrestrial Magnetism." By Sir Norman Lockyer, K.C.B., F.R.S., and William J. S. Lockyer, M.A., Ph.D., F.R.A.S. (Received January 14, read January 29, 1903.)

under five separate subheads. In this investigation only that class described as "great" has been used, since this group represented the largest disturbances.

Mr. Ellis, as already has been pointed out, has indicated the close resemblance between the sun-spot curve and that representing the variation of the magnetic elements; and it has also been shown that the curves representing the percentage frequency of prominences near the solar equator conform in the main to the general sun-spot curve.

There is, therefore, an apparent connection between phenomena occurring in the equatorial regions of the sun, the percentage frequency of prominences near the solar equator, sun-spots (which are practically restricted to these zones), and the ordinary diurnal magnetic variation.

The accompanying set of curves (Fig. 2) illustrates the great similarity between those showing the frequency of prominences in a zone about the equator (0°–20° north and south) and the variations of the mean daily range of magnetic declination; for the sake of comparison, three other curves are added, showing the variation of the mean daily area of the sun-spots for the whole, and the two hemispheres of the sun separately.[1]

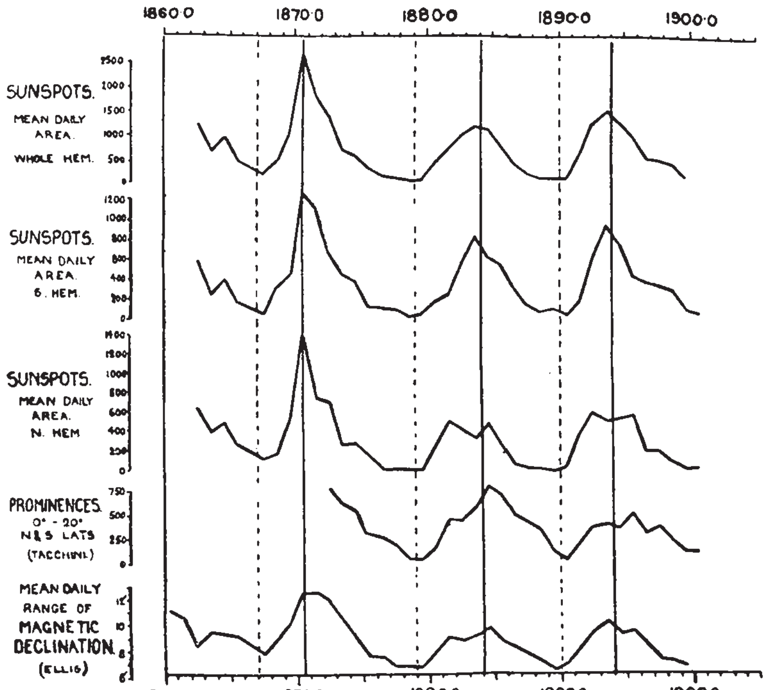

FIG. 2.—Comparison of curves representing variations of magnetic declination, solar prominences (0°–20° N. and S.), and sun-spot areas. (Continuous and broken vertical lines as in Fig. 1.)

Leaving the variation of the diurnal range of the magnetic elements and turning our attention to the magnetic disturbances, it will be seen that if a comparison of the curve representing the number of days of the "great" disturbances be made with those representing prominence frequency (Fig. 1), the former is as unlike the curves representing the prominence frequency about the solar equator as it is like those near the poles; in fact, the polar prominence outbursts and great magnetic disturbances occur almost simultaneously.

The peculiar form and general similarity of the curves can be best seen from the accompanying illustration (Fig. 3). In the figure comparison is made between the epochs of the crossing of the known and unknown lines observed in sun-spot spectra, the percentage frequency of prominences about the solar poles and Ellis's "great" magnetic disturbances.

Two curves representative of prominence frequency are given, one to indicate the abrupt nature of the curves representing the frequency in a zone near the pole 10 degrees in width (in this case 60°–70° north), and the second to illustrate polar action as a whole; this latter was obtained by making a summation of prominence frequency for the two zones 60°–90° north and south.

The simultaneous occurrence of the maxima suggests that, when the prominence action takes place at the polar regions of the sun, one effect on the earth is that we experience our greatest magnetic disturbances.

Mr. Ellis has previously stated that unusual magnetic disturbance is frequent *about* epochs of sun-spot maximum. The present inquiry indicates that not only do these "great" disturbances occur at the same time as the *polar* prominences, but the spectroscopic observations of sun-spots show that they take place not only "about" the times of spot maximum, as stated by Mr. Ellis, but when the sun-spot curve is *approaching* a maximum and at the dates of the widened line crossings, when the curve representing the "unknown" lines is on the rise, and crosses the "known" line which is descending. At the other epoch of "crossing," *i.e.* when the curve showing the "known" lines is on the rise and the "unknown" is falling, there is practically no "great" magnetic disturbance recorded.

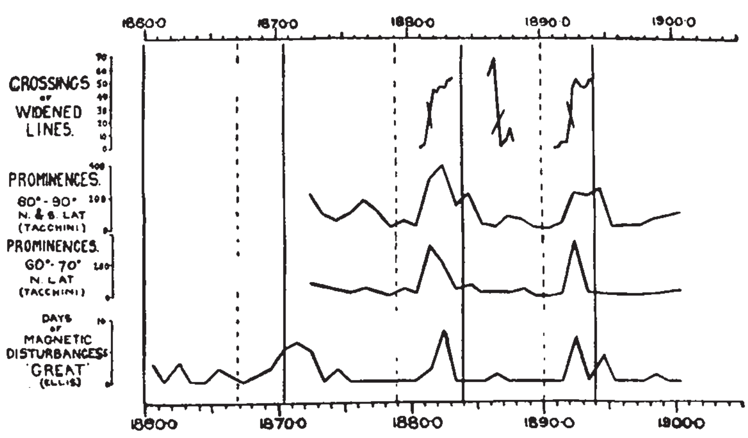

FIG. 3.—Comparison showing days of "great" magnetic disturbance, polar prominences, and crossings of widened lines. (The continuous and broken vertical lines as in Fig. 1.)

[1] In referring to the curve representing the variation of the mean daily areas of sun-spots, it may be noted that this is obtained by combining the mean daily areas of both hemispheres of the sun. A closer analysis shows, however, that this variation is not the same for both hemispheres. From the year 1862, when such a division of the sun's disc can be easily investigated, the northern hemisphere, about the time of the two last maxima, displayed double maxima occurring in the years 1881 and 1884, and in the years 1892 and 1895. About the time of the maximum of 1870 this duplicity is not so marked, although when compared with the curve for the southern hemisphere for this period, there is a slight indication of a subsidiary crest in 1872. In the case of the curve representing the mean spotted area for the southern hemisphere alone, at all the three epochs of maximum, the curves are single-crested and indicate sharply-defined maxima in the years 1870, 1883 and 1893.

From the above it will be seen, therefore, that the actual epochs of sun-spot maxima, as determined from the northern and southern hemispheres respectively, are not the same, and in dealing with the curve representing this variation for the whole hemisphere, this fact should be borne in mind. It may further be noted that the epochs of minima may be practically considered the same for both hemispheres.

This apparently close connection between solar prominences and magnetic storms perhaps explains why it is that the latter sometimes take place when there are no spots, or no very large spots on the solar surface. Thus, for instance, there may be prominences and magnetic storms when there are no spots; prominences may also sometimes be associated with large spots, and as the latter can be seen while the former cannot, the resulting magnetic storm is generally attributed to the spots.

Further, the magnitude of magnetic storms appears to vary according to the particular position as to latitude of the prominence on the sun's disc. The nearer the poles (either north or south) the prominence occurs, and these are the regions where no spots exist, the greater the magnetic storm.

In conclusion, it may be stated that the inquiry has shown that the variations of the general magnetic phenomena, as given by Ellis, synchronise with the occurrence of prominences about the solar equator, while his "great" magnetic disturbances occur, in point of time, with the appearance of prominences in the polar regions of the sun. Prof. Bigelow has recently (U.S. *Monthly Weather Review,* July, 1902, p. 352) investigated the variations in the horizontal magnetic force, and finds that the curve representing these changes exhibits subsidiary maxima which synchronise with those recorded in the curve representing the mean variation of prominences for all latitudes. Thus, to use his own words, "the remarkable synchronism between the curves cannot escape recognition, except after the year 1894, when an extra minor crest is developed in the horizontal force."

WILLIAM J. S. LOCKYER.

THE FORTRESS OF THE MOLE.

FOR the last three-quarters of a century, at any rate, natural history writers have been content to copy a diagrammatic figure of the breeding-hillock of the mole, without the least attempt to ascertain for themselves to what extent it is based on actual fact. The diagram in question was based on a fairly authentic account of the mole's habits drawn up by de Vaux just a century ago, but was elaborated by G. St. Hilaire and further "improved" by Blasius. Recently, Mr. L. E. Adams, whose special study is the Mollusca, has examined a large series of mole-hillocks in Staffordshire and has found that in no case does the structure of the one in which the nest is formed correspond with the current diagram of the so-called "fortress." His account, illustrated with numerous diagrams (two of which we are enabled to reproduce) is published in vol. xlvii., No. 4, of the *Memoirs* of the Manchester Literary and Philosophical Society. It shows that in certain other respects our ideas of the life-history of the mole require modification.

With regard to the situation of the breeding-hillock, or fortress, as it still may be conveniently called, Mr. Adams finds that this is generally in the open field, although it may occasionally be placed in a hedge-bank, but only when there is a ditch alongside. Indeed, the proximity of water seems to be the main factor in determining the position of the structure. Now and then a fortress may be found under a tree, but it is considered by the author that such a position is probably accidental.

According to the old idea, it was supposed that the runs with which it is permeated were made on a certain definite plan, allowing of free escape from the invasions of foes both above and below ground. This idea receives no support from the new observations, which tend to show that the more or less complicated galleries are purely incidental, and, with the exception of one "bolt-hole," have no reference to premeditated escape. In place, indeed, of being examples of a wonderful instinct of self-preservation on the part of their constructor, it appears that the galleries of the fortress are the natural, incidental and inevitable outcome of the work of excavating the nest-cavity and piling up the superincumbent mound.

When the site for the fortress has been fixed, a circular cavity is excavated for the reception of the nest at a depth of from two to six inches below the surface of the ground, except in the case of boggy soil or in situations liable to be flooded, when the nest is often made above the original ground-level. The easiest way to dispose of the excavated soil is to push it up to the surface, and for this purpose a tunnel is constructed, and in such a case the whole mound is made by this tunnel.

"When this superincumbent earth," writes the author, "has reached an inconvenient height, another tunnel is made, sometimes from another part of the nest-cavity (Fig. 1, *a*, *b*), but more often sideways from the first upward tunnel. All this takes time, and the mole meanwhile makes fresh runs from the fortress, the seat of its labour, in various

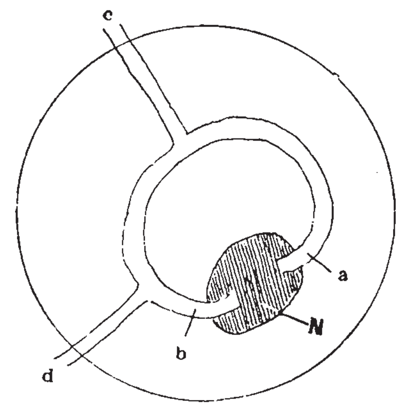

FIG. 1.—Plan of a simple mole fortress, from above. *a*, *b*, excavation tunnels; *c*, *d*, tunnels made for forming protecting heap; N, nest.

directions in search of food. Much of the earth displaced in making these fresh runs falls into the nest-cavity, and has to be disposed of in the same way as before, and also the soil displaced in making the bolt-run and the down-shaft, when this latter occurs. Now the tunnel (or tunnels) leading upwards from the nest-cavity becomes larger and larger, winding round under the surface of the growing fortress. When this removal of earth becomes too fatiguing, on account of the length of the tunnel, the mole will often begin to make new tunnels from runs close to the end of the

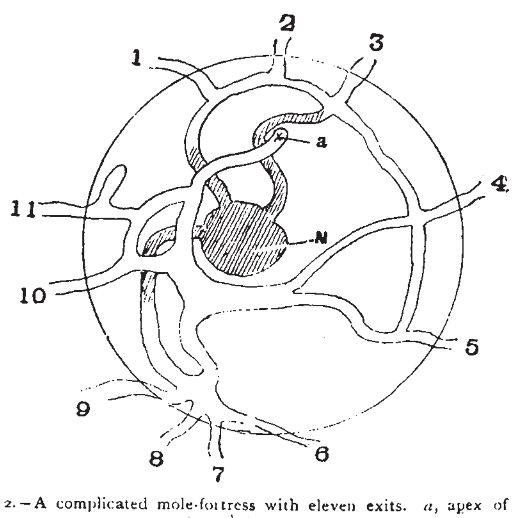

FIG. 2.—A complicated mole-fortress with eleven exits. *a*, apex of the tunnels; N, nest.

fortress. Sometimes these new runs break into those leading from the nest-cavity, but not very often; usually they lie above them."

It thus appears that the tunnels are for two distinct purposes. First, we have those formed for ejecting earth from the nest-cavity and bolt-run, which are generally in the shape of a corkscrew ascending from the nest, and often with blind divergent terminations. And, secondly, tunnels